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MAGNETOSPHERIC SPACE PLASMA INVESTIGATIONS

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by

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SCIENTIFIC INVESTIGATIONS

Equatorial Transitions

During this period we have made significant progress on a statistical study of the latitudinal distributions of core plasmas along L = 4.6 field line using DE1/RIMS data. We have studied those orbits for which the spacecraft was approximately skimming this L-shell, and for which the low-energy ions were trapped distributions at the equator and counterstreaming off the equator. We have analyzed approximately 40 such orbits, and characterized parameters such as the ratio of equatorial-trapped to 45° flux or equatorial anisotropy, the latitudinal half-width of the anisotropy, the transition latitude where ions exhibit significant anisotropy, the penetration ratio of field-aligned fluxes in the vicinity of the equator to outside the transition, and the latitudinal scale length of the trapped ion flux variations near the transition latitude. Various types of occurrence frequency relationships have been deduced. Perhaps the most interesting result is that we find an inverse relationship between the equatorial anisotropy and the penetration ratio. This is understood as the result of enhanced positive electrostatic potential associated with increased ion equatorial anisotropy producing a reduced equatorial penetration of the field-aligned ions. These results were presented at the Baltimore AGU meeting [Ref. 1], and will form the final component of the Ph. D. dissertation of Ms. J. Lin.

We have submitted a paper to the *Journal of Geophysical Research* concerning semikinetic modeling of the effects of equatorial heating and electrostatic hemispheric decoupling on early L = 4 core plasma evolution [Ref. 2]. In this paper, we have considered asymmetrical northern/southern hemispheric ionospheric flows and incorporated a generalized transport description for the electron population, which allows for consideration of electron heating effects and a more realistic calculation of electric fields produced by ion and electron temperature anisotropies. The combination of equatorially-concentrated perpendicular ion heating and parallel electron heating leads to an electrostatic potential peak about the magnetic equator which tends to shield and decouple ion flows in the northern and southern hemispheres. Unequal ionospheric upflows in the northern and southern hemispheres lead to development of distinctly asymmetric densities and other bulk parameters. Termination of particle heating causes the reduction of equatorial potential and allows interhemispheric coupling. When the inflows from the ionospheres are reduced (as may occur after sunset), decreases in plasma density near the ionospheric regions are observed, while the heated trapped ion population at the equator persists. This paper has received generally favorable comments from the referees and is in the process of being revised. A shorter version of related work for the MIT Geoplasmas workshop is in press [Ref. 3], as is the invited paper on general L = 4-7 core plasma evolution [Ref. 4].

Plasmasphere-Ionosphere Coupling

A short paper on dual spacecraft estimates of ion temperature profiles and heat flows in the plasmasphere-ionosphere system is in preparation [Ref. 5]. In this study, we have examined a limited set of DE1/DE2 conjunctions and used the temperatures obtained at two altitudes along specific field lines to integrate a simplified heat conduction dominated equation for the variation of temperature along the magnetic field lines. The resulting temperature profile is used to estimate the ion heat fluxes into the ionosphere as well as compare the profile with additional temperature points from "multiply-crossed" L-shell observations. The ion heat fluxes are observed to be in the range of 10^{-8} to 10^{-7} Joules/m^2/sec for the inner plasmasphere and up to 10^{-5} Joules/m^2/sec in the outer plasmasphere. Also, we find some cases where the additional data points on the "multiply-crossed" L-shell sets lie fairly close to the temperature profile obtained by using the highest and lowest DE1/DE2 temperature points as boundary conditions. This paper will probably be submitted to the *Journal of Geophysical Research* within the next few months.

Generalized Semikinetic Model

During this period we revised and had accepted by the *Journal of Geophysical Research* a paper [Ref. 6], in which we compare the H+/electron polar wind expansion into near-vacuum and the evolution of density perturbations, in the form of altitude-localized density cavities and enhancements, for the hydrodynamic and semi-kinetic models. In general, we have found that there is significantly less tendency to form shocks and steep gradients in the semikinetic model than in the hydrodynamic model; owing to ion velocity dispersion, such steep gradients tend to dissipate in the semikinetic description. We have also found increasing divergence between the two approaches generally as higher moments are considered; in particular, the parallel temperatures often deviate significantly. The general subject of hydrodynamic versus semi-kinetic modeling results is of significant interest currently, and we believe this work will be of substantial importance. It has been found, for the types of outflow situations considered, that the inclusion of heat flow has a major effect in bringing to closer agreement the parallel temperature profiles for the hydrodynamic and semikinetic models. A short paper on a slightly different aspect of the comparison will also appear in the proceedings of the MIT Geoplasmas workshop [Ref. 7].

Another interesting semikinetic study during this past six months concerns steady-state profiles of polar wind densities matched with the decade-old DE-1 total density profile of Persoon et al. [Ref. 8]. In this study, we used densities and drift velocities from low-altitude(2000-4000 km) polar wind observations of Chandler et al. [Ref. 9] as exobase O^+/H^+ parameter inputs for our semikinetic simulation. We found that if the combination of assumed base ion and electron temperatures is around 14000 K (e.g., T_e=9000 K, T_i = 5000 K), the resulting polar wind steady-state density profile is dominated by O^+ to beyond 8 R_E, and that we obtain a virtually perfect match with the power law profile $n_e = 490\ r^{-3.85}cm^{-3}$ observed in electron densities by Persoon et al. [Ref. 8]. A paper [Ref. 10] was submitted and accepted by *Geophysical Research Letters* during this period.

In one of the most exciting areas of progress, we have now developed a dynamic semikinetic model for examining the synergistic effects of waves and magnetospheric hot plasma populations on the outflowing ionospheric plasma. We have done this by imposing hot bi-Maxwellian ion and electron distributions at the top of our auroral simulation flux tube(4 R_E), as well as a spectrum of waves with altitude which perpendicularly heat the ionospheric ions. For example, when the hot ions are more strongly peaked at $\alpha = 90°$ than the hot electrons, a positive potential develops at the top boundary, hence downward electric fields. With transverse wave heating below, this leads to a dynamic and partially self-consistent version of the "pressure cooker" concept proposed by Gorney et al.[Ref. 11]. This forms part of the Ph. D. dissertation of Mr. D. G. Brown, who passed his oral defense in May and is now completing final correction of his thesis document [Ref. 12].

Observations of O+ Outflows

We have also addressed the quasi-statistical properties of outflowing O^+ through bulk parameter analysis of DE-1/RIMS observations when DE-1 was in the midaltitude polar cap magnetosphere. We have selected a technique which relies on analysis of the DE-1 radial head RPA data near the magnetic field direction for obtaining the O^+ bulk parameters of density, temperature and flow velocity from these measurements. We have so far analyzed thirteen passes and tested our technique with reasonably good assurance in the derived parameters. Results were presented at the recent Baltimore AGU meeting [Ref. 13]. This work completes the basic research work for the Ph. D. dissertation of Mr. C. W. Ho, who is expected to complete his dissertation in September.

Other polar outflow-related papers presented at the Baltimore AGU meeting include an invited talk on Generalized SemiKinetic models [Ref. 14] and a GSK study of ExB driven outflows in the F-region/topside ionosphere [Ref. 15]. In this latter study, all important collisional and chemical reaction terms were incorporated into a semikinetic model for field-aligned evolution of ion distributions in the 200-800 km altitude range. It was found that an outflux of O^+ consistent with observations was seen in this semikinetic study that may have been inadequately described by a related generalized transport study by Korosmezey et al. [Ref. 16].

Steep Plasmapause Transitions

In the study of ion properties in and around the regions of steep plasmapauses, we have developed a more objective and quantitative definition of 'steepness', in order to take arbitrariness out of the selection of our data samples; and in the process, we have also enlarged our data base by about 50%. With this, we have been verifying previous results, as well as examining different relationships. It appears that a significant change in temperature takes place across a steep plasmapause, increasing toward higher L shells. This may be a cause for the observed increase in O^+ concentration in this same region. However, it does not explain why O^+ is often not observed at all throughout the plasmasphere, including in the vicinity of the plasmapause. There are clearly additional processes involved, which perhaps operate on different time scales. Updated results obtained in this study will be presented to the Spring AGU meeting in Baltimore [Ref. 17]. A complete observational summary is now being prepared for submission to JGR [Ref. 18]

ULF Wave Ray-Tracing

Another study in which significant results have been obtained is the examination of the effects of heavy ions on the propagation of ULF waves in the dayside magnetosphere. We had previously seen the effects of O^+ on Pc3 fast mode waves, due to the cutoff between the He^+ and O^+ gyroresonances. The same effect is seen for Pc1 waves due to the H^+-He^+ cutoff. The difference is that the O^+ concentration is much more variable than the He^+ with solar and geomagnetic conditions. Interestingly, it was found that for a given frequency, if the O^+ concentration is raised sufficiently high, the location of the O^+ barrier is pushed beyond the magnetopause. In that case, Pc3 waves, which are thought to originate at the magnetopause, would then have greater access to the inner magnetosphere. Observations by the AMPTE CCE satellite indicate that the O^+ concentrations required for this to happen, while not typical, are not really uncommon. If this is the case, then to the extent that solar and geomagnetic conditions modulate the O^+ concentration throughout the magnetosphere, energy transport by means of ULF waves may likewise be modulated. These results have formed a portion of the Ph. D. dissertation by Mr. X. Zhang, who passed his oral defense in May and is now completing corrections to his dissertation [Ref. 19]. Initial results for Pc 3 waves have been submitted to and accepted by JGR [Ref. 20].

Nighttime Anomalous Electron Heating Events

In the statistical examination of anomalous temperature increases in the night-time F region above the Millstone Hill incoherent scatter radar, we are coming to the concluding phase.. Although this feature has been reported in the literature, it has been ascribed indirectly to photoelectron heating of plasma stored in the plasmasphere. In simulations using the FLIP model, we have been able to obtain the electron thermal structure of the F region in good agreement with the observations for nights when the temperature anomaly is not present; and interhemispheric flow of photoelectrons is included in the model. Since the same model does not produce the anomalous temperatures, some other process appears to be at work. Using a 10 year data set, we have examined the onset times, durations, intensities or magnitudes of the events, and their relation to solar and geomagnetic conditions. These results also do not appear to be consistent with a photoelectron explanation, or any other which we have tried. Most puzzling are the clear seasonal dependence (likely in the winter and absent in the summer) and the lack of correlation with geophysical conditions. While this work does not answer the question of what causes the event to occur, it does define the problem in terms of the observations and lays out the characteristics which any mechanism suggested must explain. We have presented papers on this topic to the Alabama Academy of Science and the Spring AGU meetings [Ref. 21, 22] and have submitted a report to JGR [Ref. 23].

ANALYSIS TECHNIQUES AND SOFTWARE DEVELOPMENT

Empirical Model

After propagating identifiable experimental uncertainties and counting statistical errors through the automated analysis procedures, the empirical model group (UAH, SSL, and Boeing) have concluded that systematic differences between the temperatures determined by the different heads are a larger source of uncertainty than those associated with scatter in the data. The magnitude of these differences vary with plasma conditions in ways that are not yet predictable and, hence, cannot be rectified with assurance.

MEETINGS

Dr. Wilson was co-convenor (with Dr. C. J. Pollock, SSL) of the Fifth Workshop on Dusty Plasmas, Huntsville, AL, March 22-24, 1993. Drs. Comfort [Ref. 24] and Horwitz also participated, along with a number of students. Dr. Comfort also attended the Alabama Academy of Science Meeting held at UAH, March 24-26, 1993 [Ref. 21, 25]. Drs. Horwitz, Wilson, and Comfort and Ms. Lin attended the Spring AGU Meeting, Baltimore, MD, May 24-28, 1993, where they were authors or co-authors of 6 papers [Ref. 1, 13-15, 17, 22].

PUBLICATIONS

In addition to those noted above, the following papers are at the indicated stage in the publication cycle:

Papers published are those on:

The COSPAR paper on semikinetic modeling of plasma flow on outer plasmaspheric field lines [Ref. 26] has appeared. An advance contained in this work is the incorporation of the ionospheric transition region so that the lower boundary in some of the cases contained here is only 500 km altitude. The paper on charging of ring dust clouds [Ref. 27] has also appeared.

Papers accepted and in press are those on:

A meeting report on the Guntersville Magnetospheric Plasma Models was accepted for publication in EOS [Ref. 28], and should appear shortly. The invited paper on plasma transport using semikinetic models [Ref. 29] for the Rarefied Gas Dynamics proceedings has been accepted and is in the process of being typeset for final publication. The paper on Pc 3 wave propagation will appear in JGR [Ref. 20]. MIT workshop proceedings papers [Ref. 3, 4, 7,] are in press. The paper on comparison of semikinetic models in polar wind studies [Ref. 6] will appear in JGR and the paper on warm O^+ in the polar wind [Ref. 10] will appear in GRL.

Papers submitted are those on:

equatorial heating [Ref. 2], ionospheric electron temperature anomalies [Ref. 23], comparison of hydrodynamic and semikinetic models [Ref. 30], and a survey of pitch angle distributions at high latitudes [Ref. 31].

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